Reaching Errors Under G-Loading (and vibration)

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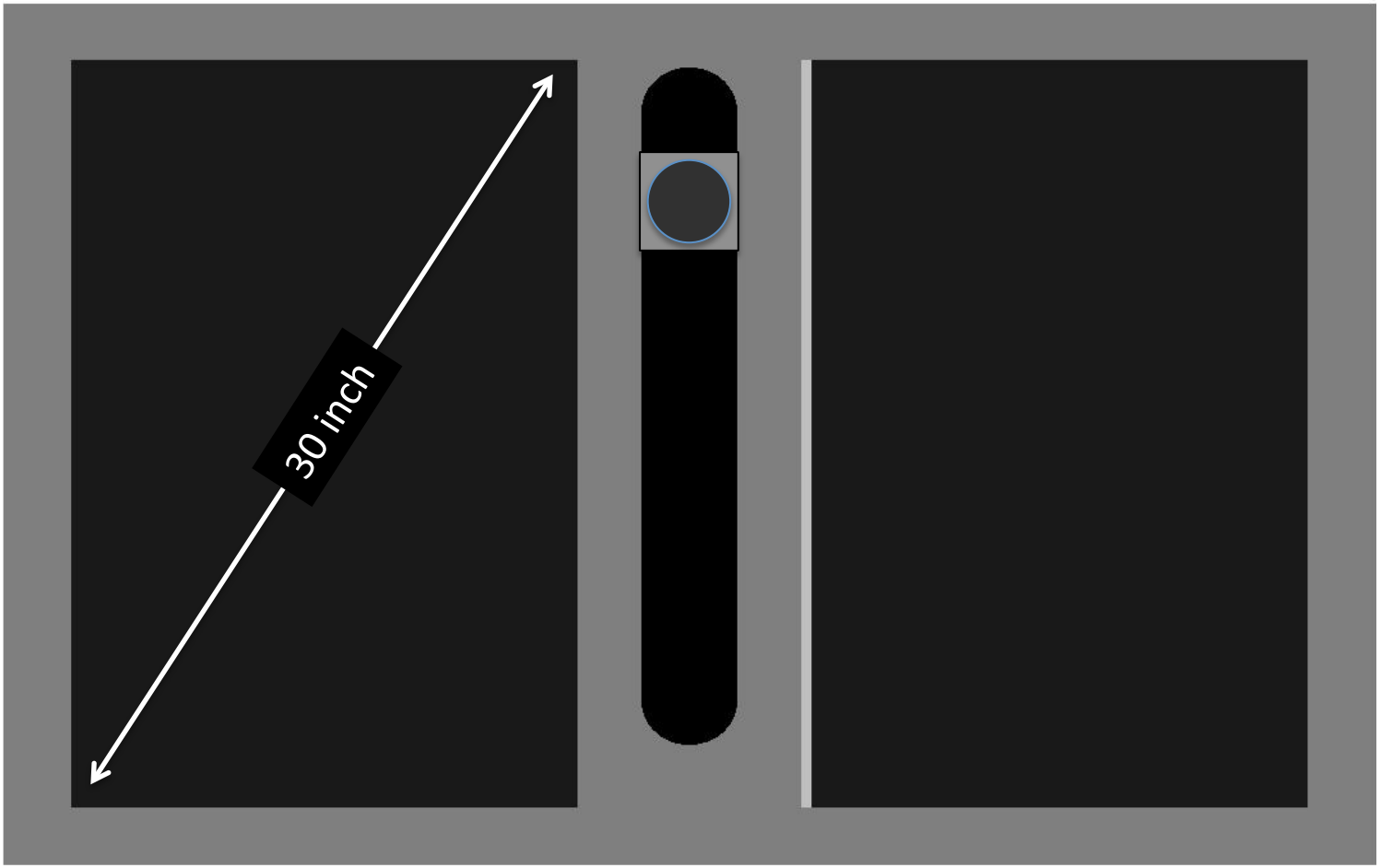
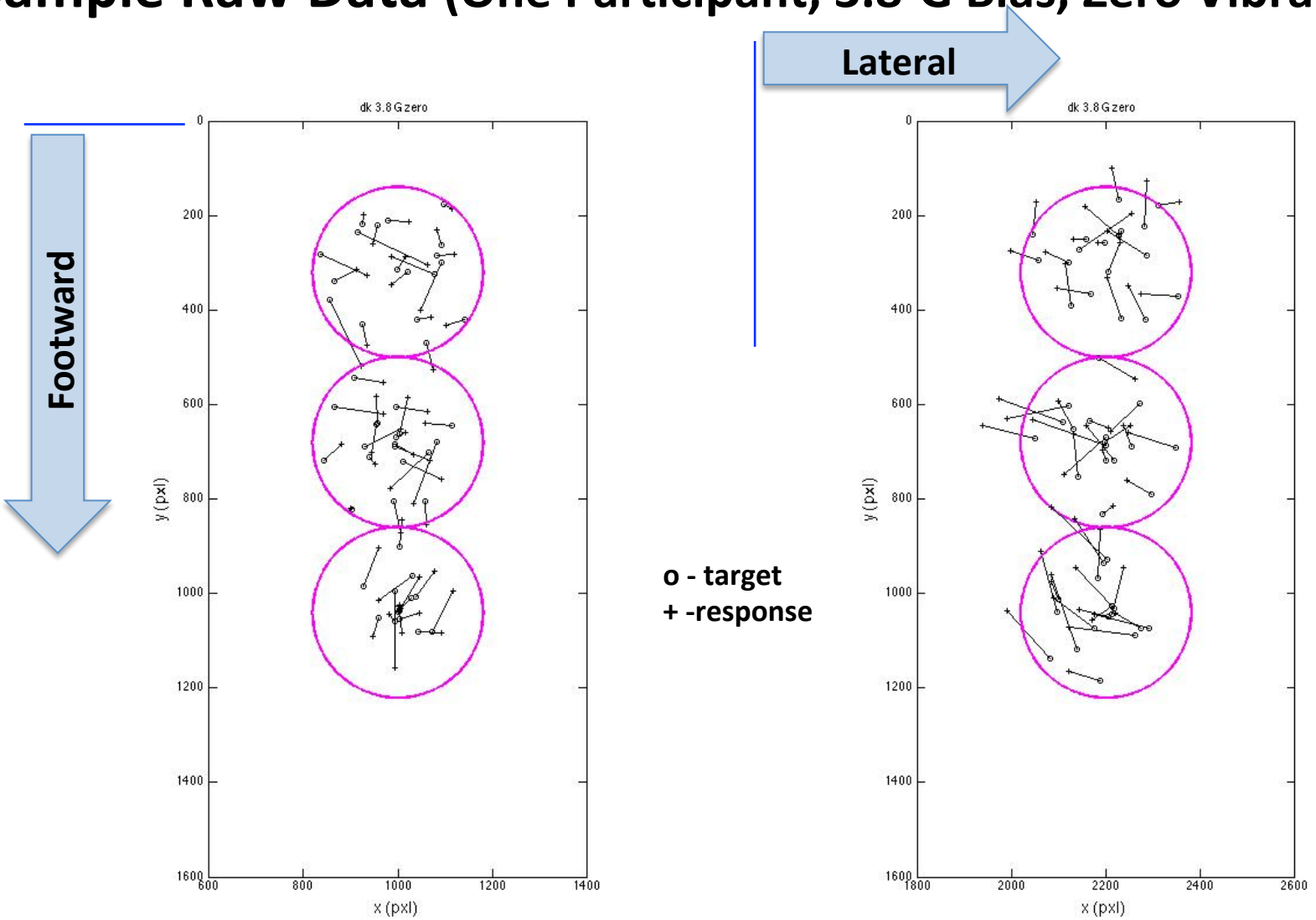
Dual Display Touchscreen Panel
With High-Resolution High-Frame-Rate Camera



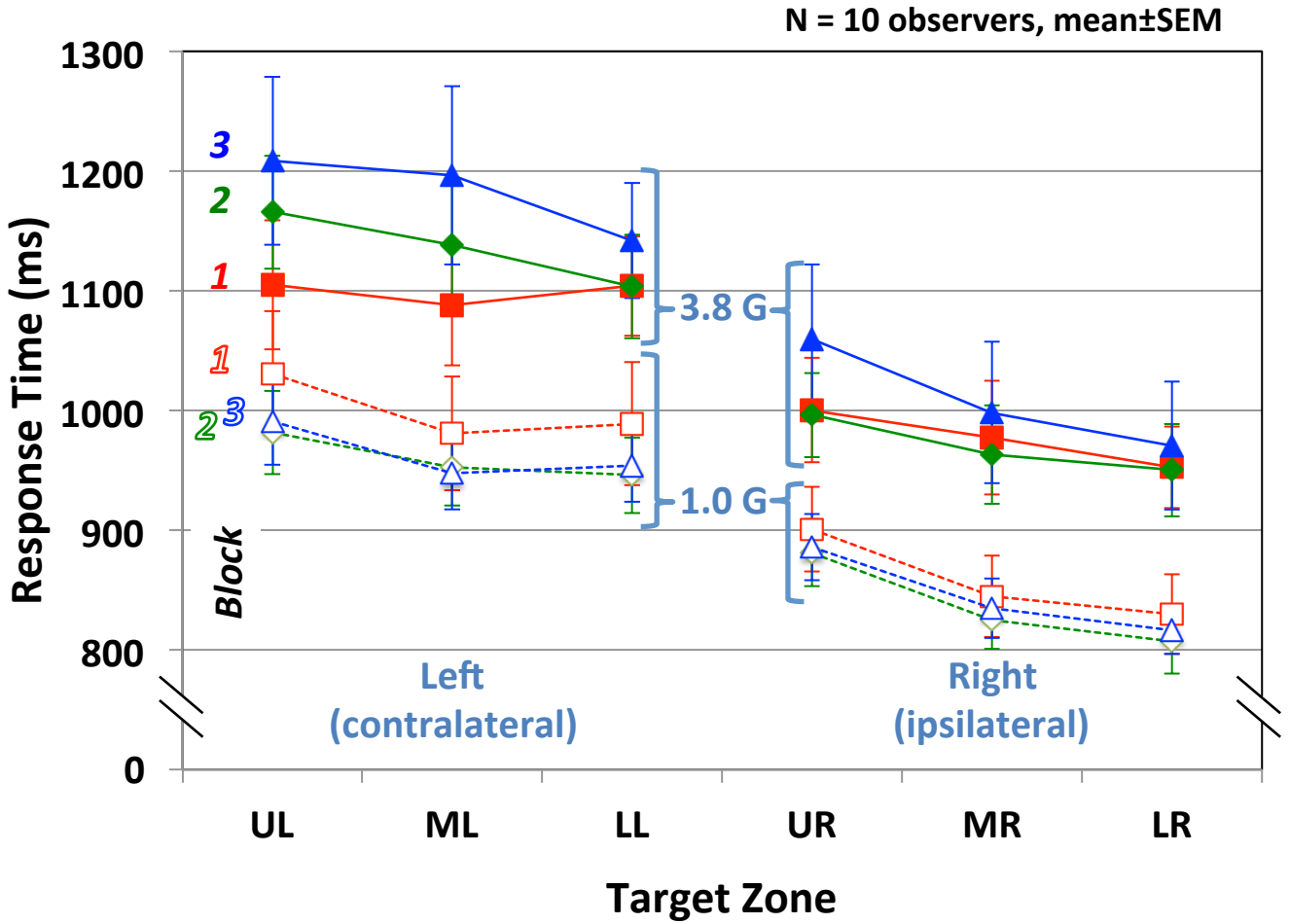
- Apple 30-inch HD Cinema Displays equipped w/ touchscreen
- 2560 X 1600 pixels (vertical X horizontal) per panel
- 100 pixel/inch resolution (30 pixel/deg visual angle)
- Viewing Distance 18 in

Sample Raw Data (One Participant, 3.8-G Bias, Zero Vibration)



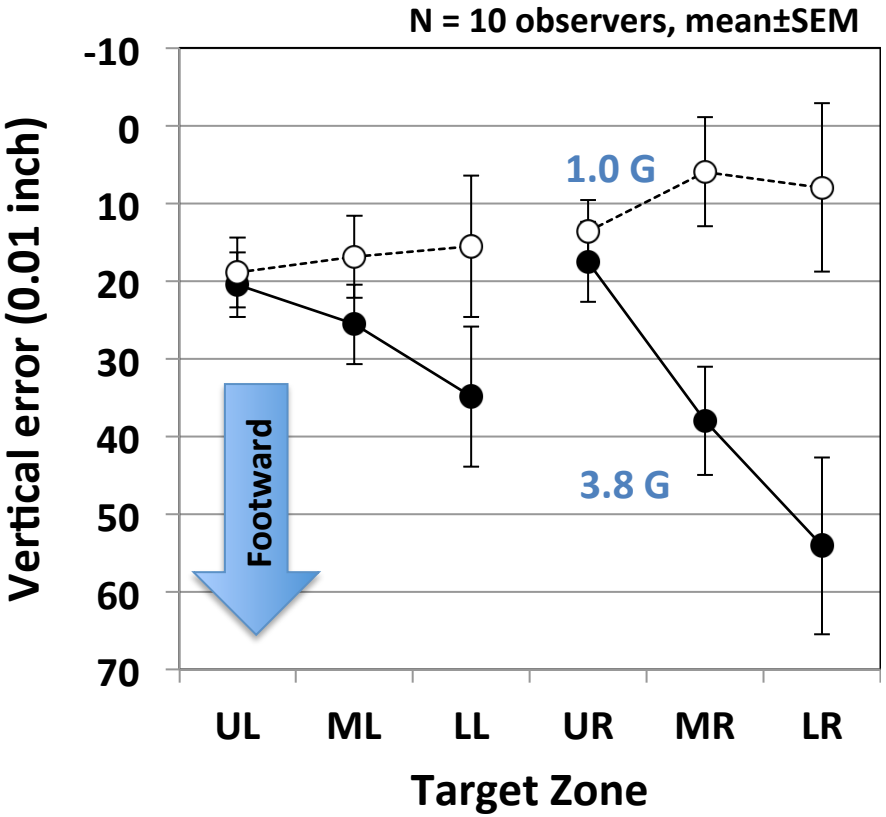
- Three target zones each panel
- Target zone diameter: 3.6 inch (360 pixels)
- Vertical zone separation: 3.6 inch (360 pixels) center-center
- Horizontal zone separation: 19.4 inch center-center (~±30° visual from midline)

Manual Pointing Response Time by Target Zone
(and by block)



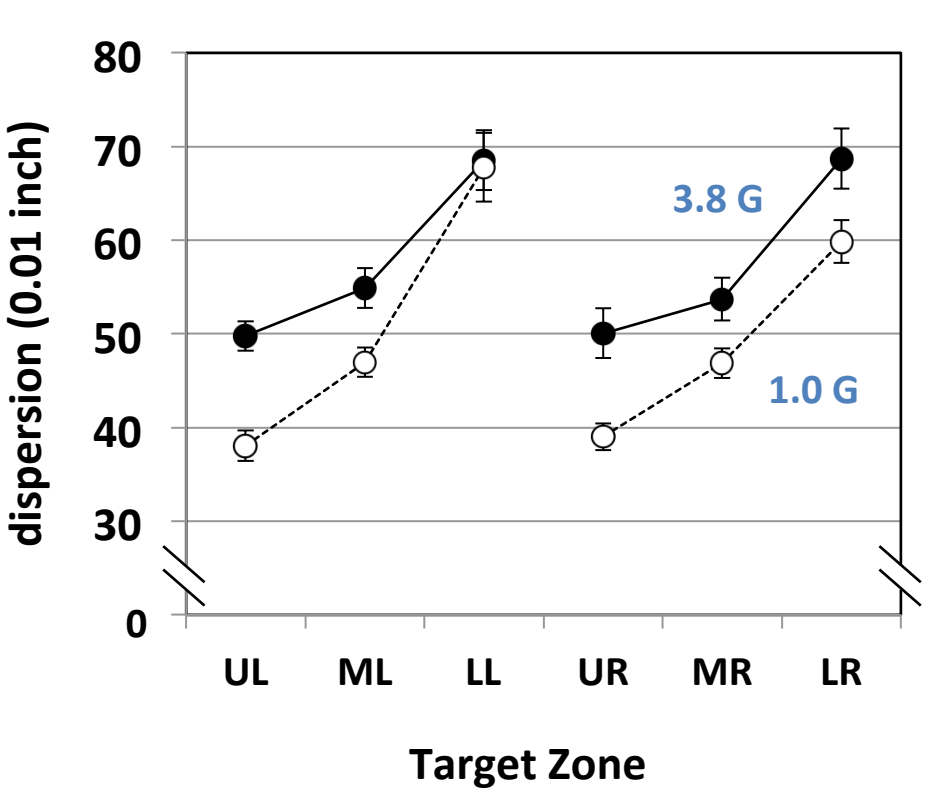
- 3.8 G_x load slows response by about 150ms
- Slower responses to contralateral and upper targets.

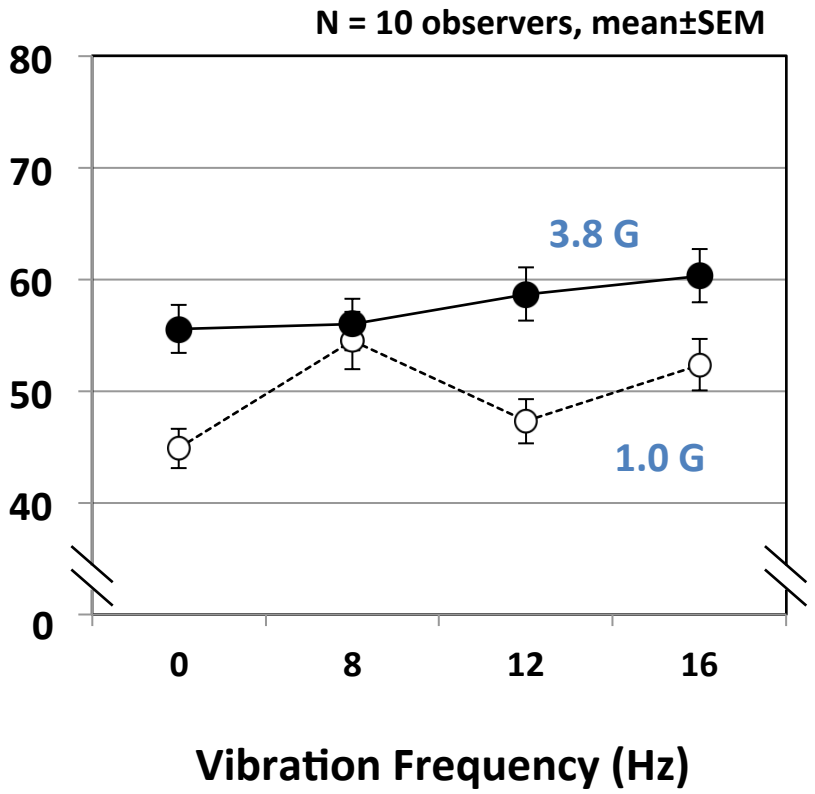
Systematic Vertical Response Error



- Significantly greater systematic footward error at 3.8 G_x
- More pronounced for lower ipsilateral (right) targets
- ~0.75 inch for 95% confidence

Vertical Response Precision (Error Dispersion)





- Greater vertical random error (dispersion) at 3.8 G and for lower targets
- ~1.2 inch radius for 95% confidence
- Dispersion increase at elevated G is largely independent of vibration

Summary

An ergonomic study by Schafer and Bagian indicated that:

1) Significant reduction in forward and upward arm range-of-motion occurred at 4Gx & above,
2) "The variance exhibited by the large standard errors is most likely the direct result of the difficulty in performing purposeful movement during high G-loads", and
3) Several crew/aviator participants declined to perform the task above 4 Gx.

A human-performance study Ames examining reach accuracy/precision during 3.8Gx loading plus vibration found that:

1) Reaches showed increasing systematic error as they became more footward,
2) Systematic errors were as high as 0.75 inches,
3) Random errors were as high as 1.2 inches,
4) Worst-case total error is therefore < 2 in (~95% confidence) for reaches with forward component of around 10 inches with practice (training) and no de-conditioning.

Gx accelerations generate both resistive forces that hold the arm back and lateral forces that torque the arm away from the correct trajectory. The 30-deg limit was established somewhat arbitrarily because sin(30 deg) = 0.5. Thus, this limit defines the point at which the lateral forces represent 50% of the total G-force, i.e., at 3 Gx, outside of the cone, there is at least a 1.5g force pulling the arm (torqueing the shoulder) away from the desired target. That said, the 30-deg limit does appear to fit with desired reach errors being smaller than 2 inches.

Forward work: Convert the reach data herein to angular positions in shoulder coordinates (which could potentially increase the estimated errors).